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A STUDY ON THE EFFECTS OF HEAT TREATMENT ON THE MECHANICAL PROPERTIES OF ALUMINIUM ALLOY (ADC 12) REINFORCED WITH IRON OXIDE (FE_2O_3)

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ABSTRACT

The mechanical properties of an Al–Si–Cu alloy (ADC12) reinforced with iron oxide, produced using different Heat treatment to process is examined experimentally. Experimental studies were carried out for ADC 12, ADC 12 + (5%) Fe_2O_3 and ADC 12 + (10%) Fe2O3, with three different heat treatment processes like Hardening, Annealing and Normalizing. The stir casting technique was adapted for the fabrication of the specimens. The Mechanical properties such as hardness, Yield stress, Tensile Strength and Elongation were studied for the specimens. The results obtained have shown some substantial improvements in the properties of the specimens with variations in the % composition of the reinforcement and heat treatment processes. The hardening process of the specimens has shown considerable improvements in hardness and tensile strength.

KEYWORDS: ADC 12, Fe_2O_3, Casting, Hardness & Heat Treatment

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Original Article

1. INTRODUCTION

Lately cast aluminium alloys have been used in various engineering applications because of their huge productivity, high strength, low density and comparably low costs. Considerable efforts are being made to explore the possibilities of improving the mechanical properties of Aluminium. Heat treatment of ADC 12 has shown exceptional improvements in tensile yield strengths and tensile ductility. Further the heat treated ADC 12 alloys have achieved high strengths and ductility between ~0.05%Mg and 0.17%Mg[1]. Studies on AL-SI (ADC12) composites have shown tensile strength of alloy and composite almostremains constant while compressive strength and Impact strength were reduced when the alloy is subjected to solutionising, Quenching and Artificial aging [2]. ADC12 produced by the different casting process have exhibited different mechanical properties. The specimens produced using twin rolled continuous casting and Ohnocontinuous casting process have shown a higher tensile strength, hardness and fatigue strength[3]. ADC12 aluminium alloy produced by gas induced semi-solid (GISS) technique has shown to achieve the average highest hardness of73. 2 HRB at a temperature of 170°C for 6 hours and uniform dispersion of the particles was achieved at 520ºC for 8 h [4]. The ADC 12 alloys synthesized through the Stir Casting technique with SiC as reinforcement has shown a great improvement in their mechanical properties when heat treated. An improvement of around 36% in tensile strength, 56% in 0.2% proof stress and 38% in the hardest was achieved when the composite was heat treated [5]. When ADC12 alloys were heat treated through compositional changes have shown to achieve high strengths and in as-cast conditions these values were moderate. The composition of Mg in ADC 12 affects the mechanical properties significantly under heat treatment [6].

The tensile strength and the hardness value of ADC12 increases with the addition of Al_2O_3 and Ti. He Also the tensile strength decreases when the wt% of Ti exceeds 0.04, due to the poisoning effect [7]. The effects on the mechanical properties of ADC 12 by the addition of rare earth (Er) metals have shown that there was a significant improvements in the ultimate tensile strength of ADC 12 with Er reinforcement[8]. Evaluation of micro hardness and the compressive properties of ADC 12 alloy reinforced with silicon carbide (SiC) and zircon sand ($ZrSiO_4$) particulate have exhibited good internal bonding strength, micro hardness and better compressive strength at 12Wt% reinforcement [9]. The increase in wt% of Fe_2O_3decreases the hardness value of the composite due to the imperfections created by the reinforcement. The tensile yield strength increases up to 2Wt% of Fe_2O_3 and beyond that there is a decrease in yield strength [10]. Experimental analysis of Al6061-Fe_2O_3 composite by subjected to severe plastic deformation have shown a slight increase in density and 30-40% increase in the hardness value of the Al6061-Fe_2O_3 composite[11]. Al6061 reinforced with Ferrous oxide (Fe_2O_3) have shown increased hardness value and the better load transfer between the matrix and the reinforcement resulted in an increase in Tensile strength of the composite [12]. Studies on the mechanical properties of Al (ADC12) -SiC composite in as cast and heat treated condition has shown that there is no change in the Tensile strength of the alloy and Al-SiC composite. The results also revealed that the increase in percentage of SiC resulted in increased Hardness of the composite [13]. The Heat treatment of Aluminium (ADC12) – Fly ash composite shown that the Tensile strength and the Hardness value increases with increase in fly ash content and further increased when they are heat treated [14]. The highest hardness of ADC12 alloy was 73.2 HRB was obtained when the alloy is artificially aged at 170°C for 6 hours [15]. The effect of Heat Treatment on Tensile strength of ADC12 alloy have shown under aged T6 temper of ADC12 exhibited better tensile strength when compared to Non heat treated alloy [16]. Addition of iron oxide to Aluminium has shown comparatively higher mechanical properties than the base alloy. In the present work, a new aluminium alloy reinforced with iron oxide was fabricated using stir casting technique. The effect of heat treatment process on the mechanical properties of the composites was also studied.

2. EXPERIMENTAL WORK

2.1 Materials

Commercially available aluminium (ADC12) plates, 5 mm in thickness were used as matrix alloy.

2.2 Chemical Composition – Aluminium (ADC 12)

The chemical composition test taken for the ADC12 specimen using Spark Atomic Emission Spectrometry is tabulated below. The tests were carried out using ASTM E 1251 standards.

Table 1: Chemical Composition of Aluminium (ADC 12)

Elements	Actual Values (%)
Silicon	11.232
Iron	0.733
Copper	2.003
Manganese	0.121
Magnesium	0.041
Nickel	0.047
Zinc	0.610
Titanium	0.065
Tin	0.023
Lead	0.057
Chromium	0.016

Table 1 Contd.,	
Vanadium	0.009
Aluminium	Remaining

2.3 Specimen Preparation

The stir casting technique was used in the fabrication process to produce reinforced metal matrix composites. This process also allows sufficient wetting of particle by liquid metal which allows a proper homogenous dispersion of the particles. Aluminium ADC 12 alloy is mixed with iron oxide to get the metal matrix composite. Aluminium (ADC12) is melted at 600^{o}C. Iron oxide is preheated to 350^{o}C and is added to ADC 12 in the furnace. The specimens were prepared for ADC12, Aluminium (ADC12) +5%Fe_2O_3 and Aluminium (ADC 12) +10 %Fe_2O_3respectively.

2.4 Heat Treatment Process

The different heat treatment process such as hardening, annealing and normalizing was carried out for the casted specimens. For hardening process, the specimen is heated to 430^{o}C for one hour and then cooling it rapidly by plunging the hot metal into a quenching medium. The metal is heated upto 420^{O}C for 3 hours and is allowed to cool inside the furnace itself to attain room temperature for annealing. The metal is heated upto 450^{O}C and is cooled in the room temperature for normalizing process.

2.5 Mechanical Properties

The mechanical properties test was carried out for Hardness and tensile properties. The tests were carried out based on ASTM E18- 2016 (Hardness) and ASTM A370 – 2017 (Tensile) standards. The tests were carried out on the Rockwell hardness testing machine with a range of 30 HRBW to 100 HRBW and UTM with a test range of 80 N to 400 kN capacity.

3. RESULTS AND DISCUSSIONS

3.1 Hardness

The hardness tests were carried out for the specimens under various heat treatment processes and are tabulated.

Table 2: Hardness Test of ADC 12

S. No.	Sample	Observed Values, HR15T			Average, HR15T
		1	2	3	
1	Aluminium (ADC 12)	55	55	54	55
2	Aluminium ADC 12)+5%Fe_2O_3	58	59	58	58
3	Aluminium (ADC 12)+10% Fe_2O_3	60	60	59	60

Table 3: Hardness Test of ADC 12 under Heat Treatment

S. No.	Sample	Observed Values, HR15T			Average, HR15T
		1	2	3	
1	Aluminium(ADC 12)-Hardened	70	71	70	70
2	Aluminium(ADC 12)-Annealed	69	69	72	70
3	Aluminium(ADC 12)-Normalized	50	52	52	51

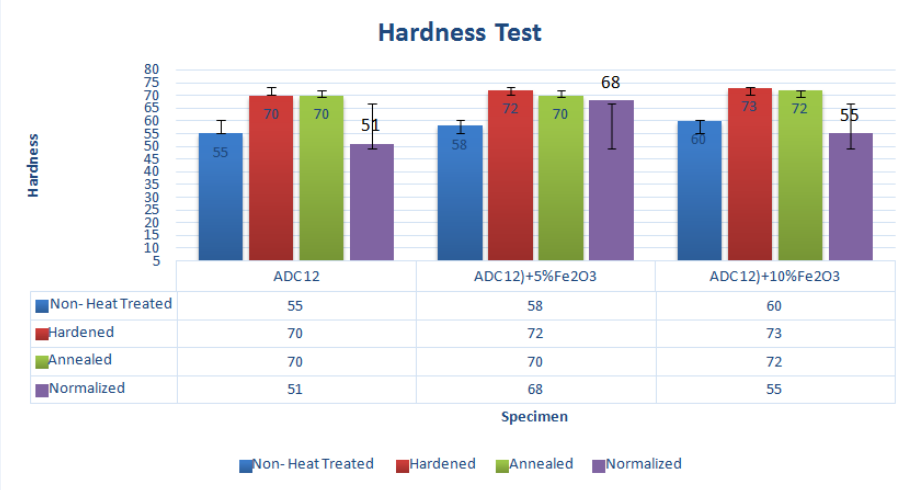
Table 4: Hardness Test of Aluminium (ADC 12)+5% Fe_2O_3 under Heat Treatment

S. No.	Sample	Observed Values, HR15T			Average, HR15T
		1	2	3	
1	Aluminium(ADC 12)+5%Fe_2O_3-Hardened	73	70	73	72
2	Aluminium(ADC 12)+5%Fe_2O_3-Annealed	69	71	69	70
3	Aluminium(ADC 12)+5%Fe_2O_3-Normalized	68	69	68	68

Table 5: Hardness Test of Aluminium (ADC 12)+10 %Fe_2O_3 under Heat Treatment

S. No.	Sample	Observed Values, HR15T			Average, HR15T
		1	2	3	
1	Aluminium (ADC 12)+ 10%Fe_2O_3-Hardened	73	73	72	73
2	Aluminium (ADC 12)+ 10%Fe_2O_3-Annealed	71	71	73	72
3	Aluminium (ADC 12)+ 10%Fe_2O_3-Normalized	55	55	56	55

The hardness test results for different specimens are tabulated and a graph has been plotted for different material composition and heat treatment. From the results obtained through the experiments the maximum value for hardness was obtained for Aluminium (ADC 12) + 10% Fe_2O_3 at hardened conditions. The test results have shown considerable improvements in hardness values for most of the specimens. The specimens which are heat treated have shown a very good improvements for hardening and Annealing where as the values of specimens which have been normalized is less compared to the other heat treated specimens. The addition of Iron oxide as reinforcement has shown an improvement in the hardness values and the maximum hardness value (73) was also obtained for the same.



The specimens have shown a considerable improvement with the percentage increase of iron oxide content.

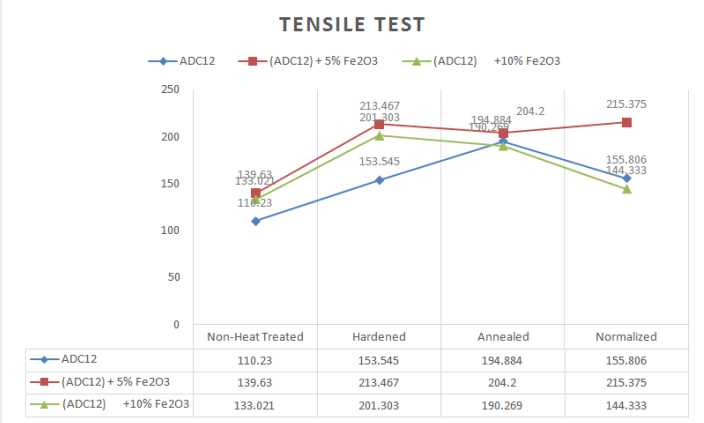
3.2 Tensile Properties

The Tensile tests were carried out for the specimens under different heat treatment processes and are tabulated.

Table 6: Tensile Test Results

S. No	Sample	Nature of Sample	Tensile Strength in N/mm^2	Elongation
1	ADC12	Non-Heat Treated	110.23	1.52%
		Hardened	153.545	3.02%
		Annealed	194.884	2.78%
		Normalized	155.806	3.04%
2	(ADC12) + 5% Fe_2O_3	Non-Heat Treated	139.63	2.14%
		Hardened	213.467	1.62%
		Annealed	204.2	3.40%
		Normalized	215.375	3.00%
3	(ADC12) +10% Fe_2O_3	Non-Heat Treated	133.021	3.02%
		Hardened	201.303	3.68%
		Annealed	190.269	4.24%
		Normalized	144.333	2.04%

The tensile test results on ADC 12 and ADC 12 reinforced with Iron oxide under various heat treatment process have shown that the addiction of iron oxide with aluminium alloy has no improvements in their properties.



ADC 12 with reinforcement have shown good improvements when compared to the original alloy in most cases. The heat treatment has improved the tensile properties to a good extent. The percentage increase of iron oxide has shown considerable improvements in hardened and normalized conditions. The maximum value of tensile strength was obtained for 5% reinforcement addition for ADC 12 under the normalized condition. Hence the usage of composite materials is increasing at an accelerated rate due to its favourable properties [17].

4. CONCLUSIONS

In this work the effect of heat treatment on ADC 12 and ADC 12 reinforced with iron oxides was investigated. Considerable agglomerations of data obtained through various tests have been tabulated. The results obtained were as follows:

- The value of hardness has improved under the addition of iron oxide has reinforcement with 10 % iron oxide addition showing an improvement of over 9 % .
- The heat treated specimens have shown a maximum improvement of 32% when compared to the pure ADC 12 alloy.

- The addition of 5% iron oxide as reinforcement has improved the tensile strength compared to the original alloy, whereas further addition has shown the values of tensile strength decreasing.
- The Tensile strength of heat treated composites have increased compared to the non-treated composite and the maximum increase was obtained for ADC12 + 5% Fe_2O_3 under Normalized condition where the improvement was over 95 % when compared to the non heat treated original alloy.
- In general, the mechanical properties of alloy has improved with the addition of Iron oxide as reinforcement, butthe amelioration of the alloy through the heat treatment process have shown a significant improvements.

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